

**IMPROVE-IT:**  
*Indices to Measure Performance Relating Outcomes, Value and  
Expenditure from Information Technology*

**Kevin Leonard, Ph.D.,**  
**Professor, Department of Health Policy, Management and Evaluation**  
**Faculty of Medicine, University of Toronto**  
**12 Queens Park Crescent West,**  
**2<sup>nd</sup> Floor, McMurrich Building**  
**Toronto, Ontario M5S 1A8**  
**CANADA**  
**W: 416-464-7885**

**Dean F. Sittig, Ph.D.,**  
**Director, Applied Research in Medical Informatics**  
**Kaiser Permanente**  
**3800 N. Interstate Ave. (CHR@WIN)**  
**Portland, OR 97227**  
**U.S.A.**  
**W: 503-335-6316**

**Abstract**

There is a revolution going on in healthcare that many people believe is long overdue. This revolution involves the application of Information and Communication Technologies (ICTs) to solve healthcare delivery system issues. Unfortunately, most of this revolution is based on just that ...beliefs! This paper describes the objectives of a research project that will test the hypothesis that increased ICT capabilities, availability, and use leads directly to improved clinical quality, patient safety, and overall effectiveness in the inpatient hospital setting.

To accomplish this, we have created a collaborative research network that is in the process of defining specific measurement indicators in an attempt to examine the existence, the timing, and the level of improvements in health outcome that can be derived from ICT investment. These indicators will then be integrated to form performance indices in three areas. These areas comprise:

1. ICT cost (both initial and on-going investment),
2. Infusion (i.e., system availability, adoption and deployment), and
3. Health outcomes (e.g., clinical efficacy, efficiency, quality, and effectiveness).

Herein, we outline the theoretical framework, the methodology employed to create the indices, and the benefits that can be obtained.

## IMPROVE – IT

### Indices to Measure Performance Relating Outcomes, Value and Expenditure from Information Technology

#### **Overview**

There is very little evidence throughout all of healthcare that provides support to the hypothesis that better information will result in better health outcomes. This research project, IMPROVE - IT, is intended to create such a body of evidence. It is our objective to demonstrate the link between improved information technology performance and increased effectiveness across a number of health outcomes. Below, we provide a case that outlines the relationship between technology and health outcomes that supports our research hypothesis.

*Consider the case of a 68 year-old man who presents himself to the hospital with slightly worsening shortness of breath, cough and a history of congestive heart failure (CHF). Routine blood work as well as an X-ray of his chest is ordered. The x-ray shows moderate enlargement of the heart which was worse than previous, but no comparison could be made because the health records department is unable to find the previous X-ray (or the report) that was performed three months ago. Further, the blood work is returned from the lab during a nursing change of shift and goes overlooked. His results showed a serum potassium of 3.1 meq/l and a sodium of 127 meq/l, down from 3.9 and 137 respectively. Finally, his weight is up by 5 lbs. since his last visit, but once again his previous lab test results and weight were not immediately available. The ER doc makes a slight adjustment to his medications, suggests he see his primary care physician in a week, and sends him home. Two days later he collapses at the Grocery store and is taken by ambulance to the emergency room where yet another chest X-ray and blood work-up is performed and he is admitted directly to the ICU.*

In this case, it is very evident that many forms of information technology would be of tremendous benefit. First, a hospital-wide information system (HIS) would have been able to retrieve the previous x-ray results and the report that clearly indicate dramatic differences. Second, the blood work abnormalities would have been flagged and an alert notification sent automatically to the patient's covering RN or MD. Had all of the right information been able to be reviewed by the appropriate clinicians, the patient may have been able to be treated with the appropriate medications and admitted to the hospital for observation resulting in a much shorter hospital stay, an overall healthier patient and much lower overall treatment costs.

In many cases, new applications could support reengineering work functions to achieve new levels of efficiency and effectiveness in daily care delivery. Many types of new "intelligent" applications could be created to exploit the data available in an electronic health record (EHR). Specific decision support tools or intelligent agents may be created on particular topics such as disease categories or healthcare best practices. Such agents could provide rules that can be applied to interpret information about a given patient. These applications can then alert healthcare providers for that patient (a family physician, for example). Coupled with scheduling applications, these solutions could significantly improve the delivery of care. Clearly, the sooner the information is garnered, the sooner the right treatment can be given. Unfortunately, it has been very difficult to measure these types of events and the related savings and health outcomes. The goal of this study is to track Information and Communications Technology (ICT) cost, implementation, usage and corresponding outcomes over a wide range of scenarios, conditions and institutions.

## **Relationship between ICT Investment and Improved Health Outcomes**

The ICT investment provides an environment for a new and comprehensive level of care to exist. That is, without new technology and better information, clinicians would not be able to deliver the effective care that they can with these investments. ICT can provide an opportunity to assess trends that formerly have taken much longer to identify. Improved information access can lead to rapid decision-making relating to that information. Often, a decision support tool is developed along with the ICT. These decisions may improve the operation of the organization: actions can now be taken sooner than they were taken historically, if they were taken at all. Finally, the ICT can be used to evaluate its own effectiveness by providing information on the improvement across a wide range of indicators.

We hypothesize that better information can lead to better care, as demonstrated by improved health outcomes. Some outcomes of better information are fewer duplicated tests, a faster turnaround in accessing reports and other patient information, and better management through trend analysis. Better health outcomes may include:

- ❑ diagnosing patients more accurately, as well as sooner
- ❑ complying with patients' wishes and comforting the family
- ❑ reducing the number or severity of errors
- ❑ supporting care delivery through better access to information

The current ICT research orientation has been on finding the optimal hardware and software configuration. What the industry now needs, however, is analysis focused on the *use* of these computerized information systems and how they can provide organization-wide benefits.

To date, there has been little evidence in the literature showing that spending on ICT leads to greater system availability, increased clinician use, improved decision-making, or better health outcomes. Recent literature has discussed measuring the value that is associated with information and communication technology (for example, Leonard, 1998; Leonard, 2004). One of the main reasons that health care systems have not widely adopted information technology is that the benefits from investment in ICT are poorly defined (Leonard, 2000). Recent studies have attempted to estimate the business value generated from ICT investment in healthcare in specific areas, but they have not recommended any method for measuring a broader (e.g., hospital-wide) effect or for dealing with the problems of partial implementation (see Rosenstein, 1999; Frisse, 1999; Agrawal, 2002; Kuperman, 2003; Wang, 2003).

In contrast to these prior efforts, our project will develop several measures that link clinical system availability, use, and cost to clinical impact over a wide range of healthcare scenarios, clinical conditions, and institutions.

As stated, the adoption of new information technology in the healthcare industry involves more than hardware and software issues. Because ICT affects ingrained business processes, health care systems need to consider the following issues surrounding any new communication technology:

1. Financial evaluation and return on investment (ROI) (Wang, 2003)
2. Difficulty in implementing these systems -- estimated failure or partial implementation rate (Southon, 1997; Jones, 2003)
3. Clinician rejection of clinical decision support, such as alert override rates (Weingart, 2003)
4. Need for national benchmarks for comparison and use by Centers for Medicare & Medicaid Services (CMS) if they are to implement and pay for Clinical Information System usage (Hatcher, 1998)

5. Need for measures of system use (Ash, 2004)
6. Need for an overall evaluation framework (Turunen, 2003)
7. Need for causal pathways for measurements to tie changes in effectiveness back to CIS availability and use (Sittig, 2004)

State of the art information and communication technology is not a substitute for high-quality clinical care. Rather, it can potentially help clinicians and ancillary personnel to improve the overall care delivery process. These improvements will not occur unless there is a concerted effort to improve the process.

One example of the complexity of implementing and benefiting from new technology involves simply the naming of a project. An implementation project originally named “electronic medication administration record system (eMAR)” was renamed after implementation at one organization to “improving the medication administration process.” Simply implementing the new online medication charting system did not solve any problems. The underlying problems were not fixed until senior medical leaders stepped in to help examine and fix the entire process—hence the need to rename the project. To reduce the number of medication-related adverse events and reduce the time from medication order to administration, this organization needed to implement, in addition to the eMAR, a computer-based physician order entry system (CPOE) with advanced clinical decision support capabilities, and a clinical results review system with relevant laboratory results. For the organization to address health outcomes, they ultimately needed to change processes and implement a more widespread system.

To evaluate the impact of advanced ICT on the health care delivery system requires not only standard measures, but the measurements must demonstrate that the ICT caused or helped cause the observed clinical outcome. Specifically, one must be able to hypothesize a potential relationship between the use of the ICT and the observed measure.

### **Research Design and Methods**

IMPROVE-IT is a research project that is intended to address these issues ... and to ultimately demonstrate the relationship between information communication and management technology and better health outcomes. Further, we wish to show not only that there are benefits from ICT investment, but also that the timing of these benefits, as well as the critical success factors, may vary.

In essence, we believe that there are 3 categories of measures that must be created. These are:

1. An accurate measure of total ICT spending throughout the hospital;
2. A detailed measure of the infusion of ICT in the organization (where infusion is defined as both the scope and the timing of implementation **and** adoption);
3. An array of health outcomes comprised of a small number of existing performance indicators that can be linked to ICT and objectively (and easily) calculated.

In the project, member hospitals will be asked to:

1. attend a preliminary meeting where member representatives will work to define and specify the measures described above;
2. attend annual meetings to report back and improve both the measures and the benchmarking;
3. provide measures on their hospital’s performance each quarter over the course of the project to a secured website.

In exchange for this commitment, member hospitals will be provided access to the secured website and all of the reported results (prior to publication). These results will be generated quarterly and will present performance measures and comparisons of individual member hospitals to an average “benchmark” as well as to other unidentified peer group hospitals.

This research will study whether increased ICT capabilities, availability, and use lead to improved clinical quality, safety, and effectiveness in the inpatient clinical setting. The logic underlying this hypothesis is as follows. 1) Investment in ICT inherently provides newer and more powerful technology and technological solutions. 2) This improvement in ICT then can generate “better” (more timely, valid, relevant, precise) information. 3) Increasing the availability and use of ICT within the health care setting makes it more likely that decision-makers will access this “better” information. 4) Finally, this “better” information allows decision-makers to make “better” decisions (those that improve measurable outcomes across a variety of dimensions).

The Improve-IT project will employ highly experienced clinical informaticians and health care service researchers. They bring with them 20 health care systems’ clinical and administrative databases and over 500,000 inpatient stays per year. These researchers and consultants will use data from these institutions to identify specific measures to be included within the indices, collect these measurements, and create benchmarks. We anticipate that the research network will grow considerably over the study period.

The remainder of this section is organized to highlight the work that we are proposing to address each of the specific aims.

**Aim 1: Establish a common set of ICT evaluation metrics to measure system cost, infusion (i.e., capability, availability and use), and overall effectiveness in the inpatient setting.**

This project is designed to address the issue of “how do we measure the effects of clinical information systems on inpatient healthcare facilities?” It is based on the assumption that before a CIS can have any effect on the organization, the system must first have at least some of the ICT functionality required to deliver the interventions that will change the patients’ and clinicians’ behavior. These behavioral changes must be great enough to generate the changes in work processes, which eventually lead to changes in healthcare outcomes. Therefore, this evaluation strategy involves the creation and measurement of three sets of key system indicators--Level of infusion (i.e., system availability and use), Effectiveness, and Cost--which when combined provide one with an overview of the effect of the CIS on the facility.

Each of the three sub-indices measures particular aspects of the CIS systems’ completeness, implementation, use, effects, or cost. While some might argue that such an index is not suitable for measuring the effects of implementing a new CIS on a facility, we argue that today’s facilities have some form of clinical information technology already helping them run the organization. Therefore, the real question is “what is the impact of adding additional CIS technologies to a partially computerized healthcare facility?”

***(i) Index of Clinical Information System Infusion***

We need the ability to accurately measure the degree of “infusion,” or system capabilities, availability and use of various clinical information system features, so that we can begin comparing CIS implementations from different vendors at different organizations. While others (Peel, 1997) have developed very technically oriented measures, we believe that we need to go beyond technical attributes and focus on the behavior of clinicians to really answer, “how integrated (infused) is the technology?”

This is not as straightforward a calculation as it would appear at first glance. Many subjective decisions are made before any data are captured or analysis produced. These subjective decisions, which relate to what to capture, how to calculate it, and how to make the analysis relevant, affect the final product. If two organizations make different decisions, even if they call the measure by the same name, the possibility is slight that they will compare identical factors. As a result, a cooperative is a necessary condition for meaningful comparisons. Once these measures have been agreed upon, then and only then, can standards and baseline benchmarks be employed industry wide.

For example, one of the most important measures of any clinical information system is its basic capabilities. It was not until this past year that any of the nationally accredited standards bodies (e.g., ANSI or HL-7) attempted to develop a standard definition of an electronic patient/health/medical record keeping system. Therefore, as one of our first group decisions, we hope to be able to identify a relatively small subset of the standard definition as a measure of an organization’s clinical information systems’ capability.

Tables 1 and 2 present a snapshot of potential clinical information system infusion metrics and some of the inherent complexities, including the subjectivity of measurement. This current thinking likely will change during the course of the Improve-IT research network discussions.

**Table 1: Basic features of a clinical information system** (From HL-7 Functionality Specification)

<b>Number</b>	<b>Function Name</b>
1	Capture Patient Demographics
2	Manage Problem List
3	Manage Medication List
4	Manage Allergy List
5	Manage Patient History
6	Clinical laboratory, radiology, EKG, procedure report – results review (1/2 point for 1 year, 1 point for > 1 year of data available)
7	Review chart summary
8	Capture and creation of clinical documents and notes by MDs and/or RNs
9	Enable medication ordering
10	Enable ordering of diagnostic tests
11	Enable placing of other orders
12	Support for referral orders
13	Ability to review radiographs online – PACS
14	Communication with Medical Devices

**Table 2: Example Levels of Clinical Information System Infusion**

Item	Definition	Score range	Level 1	Level 2	Level 3	Level 4
1	Basic types of clinical decision support	0 - 6	15 – 30% (1/6)	31 - 50% (2/6)	51 - 65% (3/6)	> 65% (4/6)
2	Basic features if a clinical information system	0-14	25 – 40% (4/14)	41 - 55% (6/14)	56 - 70% (8/14)	> 70% (10/14)
3	% clinics/units with CPOE availability	0-100%	10 – 25%	26 - 50%	51 - 75%	> 75%
4	% of orders entered by providers	0-100%	10 – 25%	26 - 50%	51 - 75%	> 75%
5	% uptime of CIS	0-100%	90 – 93%	94 - 96%	96 - 99%	> 99%
6	% of inpatient rooms with a computer or outpatient exam rooms with a computer	0-100%	0 – 24%	25 – 49%	50 – 74%	> 75%
7	% of all clinicians who use the system on a weekly basis (login)	0-100%	20 - 40%	41 - 60%	61 - 80%	> 80%
8	Workflow integration tools:	0-7				
9	CIS is primary data source: % of visits for which the CIS is used	0-100%	0 – 24%	25 – 49%	50 – 74%	> 75%
10	% of clinical decision support alerts accepted	0-100%	0 – 10%	11 - 25%	26 - 50%	> 50%
11	% of patients with an allergy documented or “no known allergies”	0-100%	15 – 29%	30 - 44%	45 - 59%	> 60%
Total	Total score is the average of all columns					

***(ii) Index of Clinical Information System Cost***

All of these new systems do not come without a cost. Measuring these costs is nearly as difficult as measuring how deeply integrated the CIS components are within the healthcare delivery system and the effects of these systems on the delivery of health care. The line between ICT costs and “process” costs are not clean. For example, many clinical operations staff support other clinicians by maintaining tables or files within the CIS (e.g., provider and charge master files, telephone and fax numbers, and terminal and printer locations throughout the hospital). Should the part of the time that these staff are pulled away from their main jobs be counted as ICT spending? In addition, costs are incurred by clinicians who spend a considerable amount of time developing standard order sets and creating and reviewing the new clinical decision support features and clinical documentation features. While these clinicians were generally not compensated for their efforts in these same areas in the paper-based world of the past, many are now realizing the importance of this work to the organization and the tremendous amount of time and effort required, and demanding payment. Finally, with the advent of the new combined

data and voice networking products, should we include all of the wiring costs as ICT costs, or should we subtract some portion of these and assign them to the telecommunications project?

These measures attempt to document the costs associated with implementing and maintaining the CIS. Although this dimension may appear to be clear-cut, once again there is much subjectivity around the boundaries of CISs and ICT and what should or should not be included.

1. Hardware – PCs, servers, printers, portable devices (3 year amortization)
2. Clinical Information System - software (initial purchase + annual maintenance)
3. ICT personnel required to keep system functioning -- help desk, hardware configuration, data base administrators, etc.
4. Training costs (initial and ongoing) – people, time off for clinicians
5. Computing infrastructure – networks, routers, cabling, wiring for terminal placement
6. Personnel (non-ICT) who spend time either entering data or producing reports and other forms of information and decision support.

A major focus will be to define and assign costs to the appropriate cost centers. Only after we have decided how to measure these costs can we begin to accurately compare ICT implementation and maintenance costs across healthcare delivery systems. Once we have agreed on these common measures, institutions will be able to track their own ICT costs, increases in CIS usage, and the resulting improvements in health outcomes over time. In addition, institutions will be able to compare themselves against the acknowledged leaders in the field.

### ***(iii) Index of Clinical Information System Effectiveness***

While measuring the “infusion levels” of clinical information systems is a relatively new concept, determinations of ICT costs and quality or effectiveness have been attempted many times before. While many have attempted to measure the overall quality of care delivered by a health care organization, few have developed a comprehensive approach to this measure. Specifically, we propose that organizations should follow the recommendations of the recent Institute of Medicine report on “Crossing the Quality Chasm” when developing their evaluation measures. For example, we believe that any CIS evaluation framework should consist of at least the following axes:

- Safe – errors of omission, (e.g., appropriate follow-up laboratory testing for dangerous medications)
- Timely – time from medication order to administration; length of stay based on selected Diagnostic Related Groups (DRGs)
- Efficient – does use of the CIS slow down clinicians?
- Quality / Effective – Errors of commission (e.g., did we do all the right things for the patients based on accepted clinical guidelines, 30-day re-admission rate, reduced infection rates in association with changes in antibiotic usage)
- Equitable – similar cancer screening rates for males/females, and without regard to race
- Patient-centered – whether the system is designed with the best interests of the patient in mind
- Organizational – effect on culture, team functioning, work process changes

We will work with the Improve-IT membership to develop a set of easily collected and objective measures of healthcare delivery system performance. Our objective is to reuse, as much as possible, available health outcome measures that are already being used in other clinical quality, safety, and effectiveness evaluation practices (such as Balanced Scorecard initiatives [Castaneda, 1998]). The following example measures attempt to document various aspects of the CIS evaluation framework outlined above.

- Medication errors (see, for example, Kaushal, 2003)
- Percent of elderly patients (i.e., >65 yrs old) taking one or more of 10 (randomly selected) medications contraindicated in the elderly (e.g., diazepam) (Fick, 2003)
- Percent of patients with renal insufficiency taking one or more of 10 (randomly selected) medications requiring appropriate drug doses or frequency adjustments (Chertow, 2001)
- Percent of patients with active prescriptions for medications known to interact (sample of 10 randomly selected high-priority medication interactions) (Peng, 2003)
- Percent of medication orders with missing or incorrect information (randomly select 10 different medications each year for analysis) (Bizovi, 2002)
- Percent of patients on medications requiring baseline and follow-up laboratory monitoring who had them done at the appropriate time intervals (sample of 10 randomly selected medication / laboratory monitoring pairs) (Schiff, 2003)
- 30-day hospital re-admit rate (Goodney, 2003)
- Length of stay per DRG (Shea, 1995)
- Hospital-wide, case mix adjusted length of stay (Pestotnik, 1996)
- Time in life-threatening physiologic state before treatment (Rind, 1994) (how do we control for hospitals with greater acuity?)
- Discharge on aspirin or beta blockers (Simpson, 2003)
- Time between medication order and administration (Mekhjian, 2002)
- Nosocomial infection rate (Evans, 1986)
- % of patients with duplicate laboratory orders for top 10 most commonly ordered laboratory tests in US (Bates, 1999)

**Aim 2: Develop a secure, interactive, web-based data collection and reporting system that allows Improve-IT members to enter their performance and compare their data anonymously with a nationwide or international sample of similar institutions.**

Once the indices have been developed and tested, we anticipate opening the site to other CIS researchers interested in using the indices to compare the performance of their hospital to others.

On the website, Improve-IT members will also be able to participate in threaded discussions and exchange documents in a reliable and secure fashion. It should be noted that while such tools may seem commonplace, and even somewhat out-dated, with the latest round of email viruses and corporate spam filters being put into place, it is getting harder and harder to communicate with colleagues via email, especially when large attachments are involved.

**Aim 3: Establish national and international benchmarks for all common evaluation measures.**

We anticipate establishing measures at the 10<sup>th</sup>, 50<sup>th</sup>, and 90<sup>th</sup> percentiles. Over time, as institutions increase the amount and sophistication of their CIS implementations, we would expect these benchmark figures to increase as well.

**Aim 4: Explore statistical relationships between measures to illustrate potential cause and effect relationships**

Success of this study would be partially defined by being able to identify interesting relationships between the various sub-indices and specific component measures within each index. In addition, we hope to uncover interesting time-related relationships. For example, we would expect to be able to demonstrate that over time, the infusion rate for any particular organization would increase. One would also hope that the effectiveness index would increase after a short lag time. It would be interesting to identify a small number of infusion measures

that were highly correlated with increases in system effectiveness (e.g., increase in percent of medication orders entered by the prescribing clinician and decreasing medication error rate).

### **Summary**

While we firmly believe that the implementation and widespread adoption of ICT throughout healthcare has had and will continue to have a significant positive effect, little evidence supports this belief. The proposed Improve-IT clinical information system value indices will demonstrate on a widespread scale the tremendous positive influence that ICT is having on health care. The goal of Improve-IT is to test the hypothesis that increased ICT capabilities, availability, and use lead directly to improved clinical quality, patient safety, and overall effectiveness in the inpatient clinical setting.

We propose to create a collaborative research network that will define specific measurement indicators, measure these indicators across organizations, and publish results that will illustrate the existence and timing of health outcome benefits derived from ICT investment. We will convene a group of experienced informaticians and health services researchers for 2-3 days during each year of the project. They will work by teleconference and an interactive website before and after these conferences, and in person at the conferences, to develop this common set of indices to measure ICT cost, infusion (i.e., system availability and use), and clinical quality, safety, and effectiveness in the inpatient setting.

### **References**

- Agrawal A. Return on investment analysis for a computer-based patient record in the outpatient clinic setting. *J Assoc Acad Minor Phys* 2002 Jul; 13(3):61-65.
- Ash JS, Gorman PN, Seshadri V, Hersh WR. Computerized physician order entry in U.S. hospitals: Results of a 2002 survey. *J Am Med Inform Assoc*. 2004 Mar-Apr; 11(2):95-99. Epub 2003 Nov 21.
- Bates DW, Kuperman GJ, Rittenberg E, et al. A randomized trial of a computer-based intervention to reduce utilization of redundant laboratory tests. *Am J Med* 1999 Feb; 106(2):144-150.
- Bizovi KE, Beckley BE, McDade MC, Adams AL, Lowe RA, Zechnich AD, Hedges JR. The effect of computer-assisted prescription writing on emergency department prescription errors. *Acad Emerg Med* 2002 Nov; 9(11):1168-1175.
- Castaneda-Mendez K, Mangan K, Lavery AM. The role and application of the balanced scorecard in healthcare quality management. *J Healthc Qual* 1998 Jan-Feb; 20(1):10-13.
- Chertow GM, Lee J, Kuperman GJ, Burdick E, Horsky J, Seger DL, Lee R, Mekala A, Song J, Komaroff AL, Bates DW. Guided medication dosing for inpatients with renal insufficiency. *JAMA* 2001; 286(22):2839-2844.
- Conrad C, Maynard, et al. Managed care, incentives, and information: An exploratory look inside the blackbox of hospital efficiency *Health Services Research* 1996; 31(3):235-259.
- Evans RS, Larsen RA, Burke JP, Gardner RM, Meier FA, Jacobson JA, Conti MT, Jacobson JT, Hulse RK. Computer surveillance of hospital-acquired infections and antibiotic use. *JAMA* 1986 Aug 22-29; 256(8):1007-1011.
- Feldstein A, Smith D, Jones S, Kovach C, Soumerai S, Simon S, Sittig DF, Laferrier D, Kalter M. Design and implementation of decision support for outpatient prescribing in an electronic

- medical record: The safety in prescribing study. *Agency for Health Care Quality and Research research on safety* (in preparation). 2004.
- Fick DM, Cooper JW, Wade WE, et al. Updating the Beers criteria for potentially inappropriate medication use in older adults: results of a US consensus panel of experts. *Arch Intern Med* 2003; 163:2716-2724
- Frisse MC. The business value of health care information technology. *JAMIA* '99; 6(5):361-367.
- Goodney PP, Stukel TA, Lucas FL, Finlayson EV, Birkmeyer JD. Hospital volume, length of stay, and readmission rates in high-risk surgery. *Ann Surg* 2003 Aug; 238(2):161-167.
- Hatcher M. Information systems' approaches and designs and facility information: survey of acute care hospitals in the United States. *J Med Syst* 1998 Dec; 22(6):389-396.
- Jones MR. Computers can land people on Mars, why can't they get them to work in a hospital? Implementation of an electronic patient record system in a UK hospital. *Methods Inf Med* 2003; 42(4):410-415.
- Kaushal R, Shojania KG, Bates DW. Effects of computerized physician order entry and clinical decision support systems on medication safety: A systematic review. *Arch Intern Med* 2003 Jun 23; 163(12):1409-1416.
- Kuperman GJ, Gibson RF. Computer physician order entry: benefits, costs, and issues. *Ann Intern Med* 2003 Jul 1; 139(1):31-39.
- Leonard KJ. Investment in information technology: The dilemma of comparing costs to benefits. *Hospital Quarterly* 1998; 1(4):53-56.
- Leonard KJ. Information systems for healthcare: Why we have not had more success -The top 15 reasons. *Healthcare Management Forum* 2000; 13(3):45-51.
- Leonard KJ. Critical success factors relating to healthcare's adoption of new technology: A guide to increasing the likelihood of successful implementation. *Healthcare Quarterly* 2004; 7(2):72-81.
- Leonard KJ, Tan JPH, Pink G. Designing health care information systems (HCISs) for integrated delivery systems (IDSs): Where we are and where we need to be", *Topics in Health Information Management* 1998; 19(1):19-30.
- Mekhjian HS, Kumar RR, Kuehn L, Bentley TD, Teater P, Thomas A, Payne B, Ahmad A. Immediate benefits realized following implementation of physician order entry at an academic medical center. *J Am Med Inform Assoc* 2002 Sep-Oct; 9(5):529-539.
- Peel V. Evaluating the cost effectiveness, impact and value of hospital IT/IS implementations - lessons learned in the United Kingdom. In: Yeoh E, ed. *Proceedings of the Hospital Authority Convention 1997 - Re-inventing health care for the 21st century*. Hong Kong: Hong Kong Health Authority; 1997, pp 67-75.
- Peng CC, Glassman PA, Marks IR, et al. Retrospective drug utilization review: incidence of clinically relevant potential drug-drug interactions in a large ambulatory population. *J Manag Care Pharm* 2003 Nov-Dec; 9(6):513-522.

- Pestotnik SL, Classen DC, Evans RS, Burke JP. Implementing antibiotic practice guidelines through computer-assisted decision support: clinical and financial outcomes. *Ann Intern Med* 1996 May 15; 124(10):884-890.
- Rind DM, Safran C, Phillips RS, Wang Q, Calkins DR, Delbanco TL, Bleich HL, Slack WV. Effect of computer-based alerts on the treatment and outcomes of hospitalized patients. *Arch Intern Med* 1994 Jul 11; 154(13):1511-1517.
- Rosenstein AH. Measuring the Benefits of Clinical Decision Support: Return on Investment. *Health Care Management Review* 1999; 24(2):32-43.
- Schiff GD, Klass D, Peterson J, Shah G, Bates DW. Linking laboratory and pharmacy: opportunities for reducing errors and improving care. *Arch Intern Med* 2003 Apr 28; 163(8):893-900.
- Shea S, Sideli RV, DuMouchel W, Pulver G, Arons RR, Clayton PD. Computer-generated informational messages directed to physicians: effect on length of hospital stay. *J Am Med Inform Assoc* 1995 Jan-Feb; 2(1):58-64.
- Simpson E, Beck C, Richard H, Eisenberg MJ, Pilote L. Drug prescriptions after acute myocardial infarction: dosage, compliance, and persistence. *Am Heart J* 2003 Mar; 145(3):438-444.
- Sittig DF. Clinical Information System Return on Investment Calculations: How do we begin moving away from association toward causation? (Presented at Association of Medical Directors of Information Systems, Orlando, FL March 2004).
- Southon FC, Sauer C, Grant CN. Information technology in complex health services: organizational impediments to successful technology transfer and diffusion. *J Am Med Inform Assoc* 1997 Mar-Apr; 4(2):112-124.
- Turunen P. A framework for evaluation of medical information systems. *Stud Health Technol Inform* 2003; 95:611-616.
- Wang SJ, Middleton B, Prosser LA, Bardon CG, Spurr CD, Carchidi PJ, Kittler AF, Goldszer RC, Fairchild DG, Sussman AJ, Kuperman GJ, Bates DW. A cost-benefit analysis of electronic medical records in primary care. *Am J Med* 2003 Apr 1; 114(5):397-403.
- Weingart SN, Toth M, Sands DZ, Aronson MD, Davis RB, Phillips RS. Physicians' decisions to override computerized drug alerts in primary care. *Arch Intern Med* 2003 Nov 24; 163(21):2625-1631.